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Interdisciplinary Strategies for Enhancing the Management of Invasive Mechanical Ventilation in Critical Care: The Integral Roles of Nursing and Respiratory Therapy

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Abstract

Background: Invasive mechanical ventilation (IMV) is a fundamental intervention for patients in critical care, yet its application often varies due to the complex interplay of patient pathology, lung mechanics, and clinician decision-making. Personalized ventilation strategies are essential to mitigate the risks of morbidity and mortality associated with improper ventilatory management.

Methods: This narrative review synthesizes the existing literature on interdisciplinary approaches to managing IMV, focusing on the roles of nursing and respiratory therapy. A comprehensive search of MEDLINE and EMBASE databases was conducted for peer-reviewed articles published in English up to 2023, systematically extracting data pertaining to clinical decision-making processes, role delineation, and the deployment of Clinical Decision Support Systems (CDSS).

Results: The findings reveal significant variability in decision-making responsibilities among healthcare professionals, with nurses often guiding assessments related to weaning readiness, while physicians predominantly oversee initial ventilator settings and extubation. The integration of CDSS into clinical practice shows promise in optimizing ventilation strategies, yet barriers to implementation, such as clinician resistance and workflow disruptions, persist.

Conclusion: Enhancing interdisciplinary collaboration and the effective deployment of CDSS are critical for improving patient outcomes in mechanical ventilation management. Future research should focus on clarifying decision-making determinants and refining implementation strategies to facilitate the adoption of best practices in critical care settings.

Keywords: Invasive mechanical ventilation, clinical decision support systems, interdisciplinary collaboration, nursing, respiratory therapy.

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1. Introduction

Invasive mechanical ventilation (IMV) is a crucial supportive therapy for patients and is the primary reason for continued critical care admissions [1,2]. Mechanically ventilated patients constitute a heterogeneous population with variations in pathology, lung mechanics, and physiology, such that improper application of ventilatory strategies can lead to morbidity and mortality [3-6]. There is a growing focus on creating personalized ventilation strategies that adapt to fluctuations in patient condition and are administered consistently [7-9].

The justification for individualized ventilation control is substantiated in several areas. For example, subgroup identification using clinical and plasma biomarker data, including hyper- and hypo-inflammatory subphenotypes in acute respiratory distress syndrome (ARDS), with potential therapeutic applications shown in several retrospective investigations [10,11]. Physiological optimization tailored to specific disease states is efficacious; patients with diffuse, hyper-inflammatory ARDS are more likely to benefit from elevated positive end-expiratory pressure (PEEP), thereby diminishing dynamic strain and atelectotrauma, while those with focal, hypo-inflammatory ARDS derive advantages from reduced PEEP, thus alleviating lung over-distension and hemodynamic alterations due to ventilation [12-14]. In patients with severe ARDS, elevated PEEP correlated with improved survival, but a ventilator strategy inconsistent with lung shape correlated with lower survival [15,16]. In this setting, optimizing and personalizing ventilator control by enhanced comprehension of disease states, such as ARDS subphenotypes, is essential for enhancing patient care.

A multitude of clinical decision support systems (CDSS) have been developed to aid doctors in accomplishing this goal. A Clinical Decision Support System (CDSS) is a computational framework aimed at improving decision-making by linking patient characteristics with a digital clinical knowledge database, offering tailored suggestions to the practitioner [17-20].CDSS for mechanical ventilation exist in various formats, ranging from independent systems to supplements of electronic health records, or web-based platforms necessitating data input, with certain ventilators incorporating integrated CDSS [21]. Clinical Decision Support Systems (CDSS) can facilitate various decisions, such as titrating ventilator settings, implementing lung-protective ventilation, assisting with weaning from mechanical ventilation, and supporting decisions across multiple domains. CDSS may optimize ventilator settings autonomously (closed-loop) or be utilized at the point of care, enabling clinicians to integrate their expertise with the recommendations provided by the CDSS (open-loop). Currently available commercial systems employ diverse methodologies to deliver clinical recommendations, including physiological models, rule-based systems, and neural networks [22-25]. The prominence of machine learning methodologies is anticipated to increase. Unlike clinicians, who may exhibit cognitive biases and limitations due to their training and experience, CDSS can consider numerous factors to enhance patient care [26,27].

This study will concentrate on open-loop Clinical Decision Support Systems (CDSS) because to its interaction with and need to engage clinicians in decision-making, as well as the possible complexities they present to the clinical setting. Due to the variability in size, resources, and staffing of critical care units, the deployment of open-loop Clinical Decision Support Systems necessitates a comprehension of optimal strategies [28,29]. The methodology derived from implementation science, which examines strategies for the systematic adoption of research results and evidence-based practices, may be advantageous. It is distinct yet shares characteristics with quality improvement and dissemination methods. Various implementation models are delineated; process models encompass action models or 'how-to-implement' guides; determinant frameworks identify barriers and enablers that affect implementation outcomes; and several theoretical approaches have also been published [30]. Of particular relevance to Clinical Decision Support Systems (CDSS) is the Technology Acceptance Model (TAM), which considers the end-user's behavioral intention to utilize a device (as a proxy for device acceptance), influenced by the perceived usefulness and ease of use of the device. Subsequently refined to incorporate the influence of social norms (TAM2), a comprehensive model, the Unified Theory of Acceptance and Use of Technology (UTAUT), was developed. Such frameworks offer a valuable construct to inform implementation efforts [31].

The effective deployment of open-loop Clinical Decision Support Systems necessitates the identification of stakeholders and comprehension of existing practices. This includes mapping clinical workflows, identifying determinants of decision-making and interactions with the ventilator, comprehending the clinical environment, delineating process measures to characterize decision-making quality, and establishing quality metrics for benchmarking purposes. Decisions not solely grounded in clinical facts, but affected by variables like as perceived responsibility, staff composition, or stress, need scrutiny. This will result in more sophisticated and adaptive CDSS architecture.

2. **Methodology**

This research was classified as a narrative review due to its extensive breadth, which typically aims to address a single, unique inquiry. Nonetheless, we used the methodological rigor characteristic of a systematic review to guarantee the extraction and evaluation of the majority of available material on this subject.A search method was designed to locate papers published in MEDLINE (Ovid) and EMBASE. We included publications published in English in peer-reviewed journals up to 2023.

3. Determinants influencing decision-making and job assignment in mechanical ventilation

Decision-making in adult and pediatric critical care is well-documented and has commonalities in the literature. Eight critical ventilation choices are delineated, with responsibility for these decisions often distributed. Senior physicians predominantly determine initial ventilator settings and weaning strategies, as well as lead decisions regarding extubation readiness and the commencement of noninvasive ventilation. Conversely, nurses are more likely to take the initiative or collaborate with physicians in assessing weaning readiness and failure, as well as in titrating ventilator settings [32-35]. The degree of nursing autonomy fluctuates, peaking in units with a nurse-to-patient ratio of 1:1. When modifying the ventilator, nurses primarily adjust the fraction of inspired oxygen (FiO2) and ventilatory frequency, although nurses in Australia and New Zealand report feeling more empowered to modify pressure support than their European counterparts. Nonetheless, the perceived role in decision-making differs among professional groups. Norwegian research indicated that nursing directors saw their autonomy and influence as greater than that seen by doctors [36].

The nature of the choice also differs based on the professional group. Curtis and colleagues [37] discovered that, when evaluating hyperoxaemia comprehension in critically ill patients, nurses utilized both objective and subjective criteria and were generally not responsible for operating the ventilator; respiratory therapists adhered to protocols while executing care objectives; physicians applied condition-specific treatments that did not depend on standardized management.

The country impacted the decision-making profile, with Switzerland and the UK exhibiting a propensity for collaboration, while Italy and Norway demonstrated a tendency towards physician-led practices. An ethnographic study conducted by Villa and colleagues [38] investigated the role of nurses in Italy, revealing that nurses seldom initiated weaning or extubation, instead providing recommendations that required physician authorization. Alkhathami and colleagues [39] evaluated conceptions of roles and duties in Saudi Arabia; unlike Western Europe, they found that doctors and respiratory therapists cooperated on critical choices, with little nursing participation.

Nurse-led weaning is directed by physiological criteria that determine a patient's 'weanability,' encompassing gas exchange, respiratory effort, pulmonary condition, cardiovascular stability, and infection indicators [40-44]. Subjective knowledge of the patient, obtained through consistent assessment and clinical examination, is integrated with objective data from observations and investigations. Additional factors influencing weaning include the patient's medical history, nutritional status, metabolic indicators, psychological health, and an evaluation of the potential for clinical deterioration. Not all nurses utilize every piece of evidence; less experienced nurses require more guidance, and criteria vary at different stages of the weaning process [45,46].

Moreover, variability in nursing practice is affected by professional knowledge, training level, role and area of practice, experience, personality, and confidence [45,47]. Nursing practice is influenced by the duration of patient interaction, which is essential for comprehending and addressing their condition; acknowledging fixed criteria from protocols that may not always be applicable due to variations in patient presentation and pursuing a personalized approach instead; and ensuring the quality of care during shift transitions and handovers. Weaning decisions are frequently made through a trial-and-error methodology. Two psychological concepts characterize differing approaches to ventilator adjustments: focus gambling (modifying multiple settings simultaneously) and conservative focusing (altering a single setting) [43,44,48,49]. Professional accountability, the capacity to rationalize decision-making, particularly when deviating from protocols, and assuming overall responsibility for weaning, also delineate a nurse's scope of practice and their level of independent decision-making [50].

Systemic or structural factors, encompassing the working conditions of the clinical team, interprofessional communication and collaboration (especially with physicians), resource availability, and adherence to unit-based protocols that influence clinical practice, are also significant [44-47].

4. Factors that influence physician-directed weaning from mechanical ventilation

Physicians utilize three categories of information to make weaning decisions: empirical objective (physiological measurements), empirical subjective (clinical examination), and abstract (intuition based on experience) 51]. Physicians strive to provide care that is adaptable and customized for each patient. Facilitative weaning strategies are developed through various approaches: instrumental (optimizing physiology), interacting (through social interactions), process-oriented (goal-related), and structural (individual and organizational competence). Additionally, physicians incorporate insights from the multidisciplinary team to inform their decisions [52].

This individualized approach results in heterogeneity. Tulaimat and Mokhlesi53 used clinical vignettes to evaluate physicians' decisions about extubation; the concordance between any two clinicians was moderate and peaked among professionals from the same institution. One-third depended on the breathing pattern during pressure support, fifty percent relied on the acid-base status, while a smaller proportion used mental state evaluation or the amount of secretions. In addition to demonstrating considerable variation in the parameters influencing extubation, the precision of physician extubation choices was inadequate [53].

No papers were identified that delineate the procedure for mechanical ventilation. Research by Tate and colleagues [54] identified variables contributing to delayed extubation; due to the majority of spontaneous breathing trials (SBTs) occurring overnight, there were considerable delays between the SBT and the extubation decision (average duration 3–6 hours). The majority of professionals believed this duration was excessive and adversely affected patient outcomes. The delays were attributed to systemic concerns, such as postponing decisions to the day team or awaiting the presence of a senior doctor.

Two systems identified in the literature are Extubation Advisor, a web-based clinical decision support system, and a computerized lung-protective ventilation clinical decision support tool for patients with ARDS [55,56]. Despite variations in design, functionality, and decision-making support, facilitators and barriers to implementation can be broadly categorized into those affecting the clinician, the intervention, and the organization. Facilitators for clinicians included confidence in utilizing the CDSS, comprehension of the underlying disease pathology, and maintaining autonomy in decision-making. Conversely, barriers encompassed a perceived diminishment of the clinician's role, apprehensions regarding job security, and ambiguity about when to deviate from the protocol. The facilitators of the intervention included a userfriendly interface, seamless workflow integration, and efficiency with minimum training, whereas the obstacles included the additional time needed for documentation. Facilitators of the system comprised the belief that the implementation of the Clinical Decision Support System (CDSS) was a mandate at the system level, while barriers encompassed inadequate communication from clinical leaders, inconsistency in training due to differing work schedules, limited accountability among local leaders, and restricted access to technical support.

Similarities were seen in Morris [57]'s account of the obstacles and enablers to the deployment of computerized procedures in critical care. Clinician facilitators encompassed a personal dedication to research and quality enhancement; intervention facilitators comprised demonstrable positive outcomes with the device; and system facilitators involved incentives for patient enrollment, the impact of senior clinicians, and the effect of peer pressure. Clinician barriers encompassed the undue emphasis on personal experience and clinician pride; intervention barriers involved the exclusion of end-users from device development and excessive complexity in data entry; and system barriers were characterized by inadequate technological infrastructure.

A systematic review evaluating the execution of care bundles identified various factors applicable to the implementation of Clinical Decision Support Systems (CDSS). Facilitators for implementation predominantly emphasized systemic elements, including the endorsement of senior leadership, multidisciplinary, practice-oriented training, consistent performance assessment, ongoing education, regular audits, a dedicated implementation team, and a supportive unit culture. The apprehension of potential injury to patients was recognized as a significant obstacle to the adoption of any new treatment procedure [58].

5. Strategies for the implementation of clinical decision support systems

Morris [57] enumerates many aspects that advocate for the introduction of CDSS. This encompasses explicit logic, regulations, and thresholds for variables that eliminate the necessity for clinical judgment or opinion; incorporation of all outcomes to which protocol rules pertain; formulation of clear, unequivocal instructions; and point-of-care implementation that is integrated with hospital electronic systems. The significance of identifying, documenting, and assessing clinician non-adherence to Clinical Decision Support Systems (CDSS) is addressed as a component of a dependable monitoring and evaluation program. This data, in conjunction with information on protocol performance, furnishes evidence for continuous enhancement. He also underscores the significance of the availability of technical and clinical assistance at all times [57].

Two studies propose implementation strategies for care bundles and procedures in the critical care unit, which may be applicable to Clinical Decision Support Systems (CDSS). Moraes and colleagues [58] advocate for frequent instructional sessions, supplemented by tools like posters, with ongoing education via case studies and practical applications. Additional treatments include the engagement of local leadership, implementation of audits, expert evaluations, patient-centered initiatives, and tailored methods for each department.

6. Discussion

Our narrative evaluation of 30 research has uncovered numerous significant results and identified gaps in our comprehension. Mechanical ventilation is a multifaceted clinical procedure, characterized by several decision points, executed by personnel from diverse professional disciplines with varying levels of expertise and experience. Substantial variability is present throughout the process, including decisional duty, the information used for decision-making, and the thresholds for risk and judgments. Clinical Decision Support Systems for mechanical ventilation are rare and encounter several obstacles to deployment.

Our literature research indicates that job allocation for ventilation management is well delineated. Nurses mostly guide judgments about weaning readiness and failure, whereas doctors primarily oversee decisions related to initial ventilator settings, weaning methods, and extubation readiness.

Interprofessional collaborative decision-making is crucial and exhibits similarities in adult and pediatric critical care; however, it differs between countries, with Western European nations promoting more nurse autonomy. Divergences in training prerequisites and cultural influences (e.g., more hierarchical or paternalistic healthcare models) may explain this variability in outcomes. Nursing autonomy and decision-making impact are contingent upon the nurse:patient ratio, being more prevalent in a 1:1 ratio scenario. The culture of a unit, together with diminished perceptions of reprimand, fosters more autonomy among younger staff and indicates potential disparities across units with differing leadership models, sizes, staff experience, and composition; this signifies a prospective avenue for further study. No information was available about clinical workflow; however, one research investigated the factors contributing to delays in extubation. Furthermore, no studies delineated process parameters of ventilation, other from morbidity, mortality, and weaning success, the latter of which has several definitions [59].

The weaning process from mechanical breathing has been examined more comprehensively, particularly on the variables that affect nurse-led weaning, which are categorized into patient, nurse, and system aspects. The investigation of medical decision-making about weaning was limited, with existing research revealing considerable variability in practice, descriptions of customized techniques, and a lack of information examining the influence of clinician specialization, experience, or training level. Physicians, although using both factual and subjective data, were more inclined to rely on intuition based on patient characteristics and their own experience. Our analysis indicates that the potential benefit of Clinical Decision Support Systems (CDSS) may be seen in the weaning process from mechanical breathing. Early extubation diminishes the likelihood of nosocomial pneumonia and ventilator-induced lung injury, as well as the expenses linked to extended intensive care stays. However, hasty cessation of ventilation may result in respiratory muscle fatigue, inadequate gas exchange, and heightened morbidity and mortality. The success rate of physician-directed weaning is suboptimal, with some studies indicating rates below 50%; therefore, Clinical Decision Support Systems (CDSS) may emphasize this facet of mechanical ventilation [60-62].

Research using clinical vignettes illustrated the disparity in medical practice regarding the administration of fluids or vasopressors in septic shock. The authors identified significant diversity in the combination of quantitative measurements used. Physicians solicited data that they later said they would not use. Over one-third of participants used 'gestalt' in their clinical decision-making. The initiation of vasopressors often relied on systemic factors, such as patient location, availability of support personnel, and access to technology. Fluid administration exhibited significant variability regarding the initial bolus, total volume administered, and the volume at which vasopressors were initiated. By examining clinical decision-making, which can be somewhat binary (i.e., administering either fluid or vasopressor), and highlighting substantial practice variation, this underscores the intricacy of characterizing clinical behavior. This presents an even greater challenge for mechanical ventilation, which has several factors to consider [63].

Allerød and colleagues [64] assessed doctors' perspectives on ventilator settings produced by a decision support system vs those proposed by their peers over 10 simulated instances. The research aimed to eliminate heterogeneity in patient condition by using same vignettes and consistent CDSS physiological models, therefore concentrating only on decision-making. Clinician preferences about ventilator settings and the resultant simulated values were markedly disparate. doctors had a negative perception of both the guidance offered by the Clinical Decision Support System (CDSS) and their peers, deeming the advise undesirable in one-third of instances. Additionally, doctors were asked to evaluate each item of advice, revealing significant variability in the rankings, hence indicating seldom consensus among physicians.

The situation is further compounded by the inconsistency in terminology pertaining to critical care and treatment requirements. A systematic review by Hakim et al. [65] identified considerable heterogeneity in the definitions of acute respiratory failure and intubation criteria, with diverse physiological metrics and descriptions of heightened respiratory effort employed across 50 trials, alongside inconsistent criteria for determining the necessity of intubation. Establishing standardized criteria for intervention will be essential in reducing variability in practice.

While no research investigated decision-making in the context of Clinical Decision Support Systems (CDSS), many examined the facilitators and obstacles to the introduction of CDSS and care procedures in critical care settings. These may be roughly classified into categories pertaining to the physician, the intervention, and the organization. While we identified research demonstrating the therapeutic and economic benefits of CDSS, no studies outlined potential processes for CDSS. While not within the purview of this research, Arnal and colleagues demonstrated that INTELLiVENT-ASV, a closed-loop Clinical Decision Support System, significantly decreased the frequency of manual ventilator setting adjustments, highlighting the potential of such devices to enhance clinical workflow [66].

A study identified factors that facilitate the implementation of open-loop Clinical Decision Support Systems (CDSS), which include integration with existing electronic health records, comprehensive monitoring and evaluation, sufficient technical and clinical support, and regular assessment of clinician interactions with the CDSS, including instances of non-adherence. Clinician feedback aimed at enhancing CDSS can be framed within the concept of a 'learning organisation,' which emphasizes collaborative efforts among employees to foster collectively accountable change, encompassing disciplines such as team learning and systems thinking [67]. It is crucial to evaluate how this methodology aligns with contemporary randomized controlled trials (RCTs), as it inherently disrupts blinding and independence protocols. Consequently, innovative methods for evidence creation and application are necessary. No research was identified that used implementation methodologies or frameworks, including the UTAUT.

Despite the growing body of data supporting cost-effective therapies, many are not integrated into practice. The adoption and acceptance of therapeutic interventions remain difficult and sluggish. Essential to surmounting these obstacles is the demonstration of clinical efficacy for the patient and economic benefit for the healthcare organization. To mitigate the 'second translational gap' (the disjunction between research and clinical application), a method using implementation science should be considered. This approach should be multidisciplinary to identify factors affecting the patient, clinician, organization, broader healthcare community, and policy environment. We propose that this approach will enhance the adoption of Clinical Decision Support Systems (CDSS) for mechanical ventilation and facilitate the implementation of best practices and shared learning [68].

This assessment acknowledges the difficulty of tackling this problem without factoring in business considerations. Decision-aiding gadgets are categorized as medical devices and cannot be subjected to trials without obtaining appropriate regulatory permission. In the UK, medical devices may need a clinical study (a prospective clinical trial) to demonstrate safety and performance under standard settings, within its intended use. A clinical trial requires clearance from the Medicines and Healthcare products Regulatory Agency (MHRA) and the Health Research Authority (HRA), together with an independent ethical assessment by a research ethics committee, prior to its implementation. In addition to the time necessary for these approvals, there is a significant charge linked to the application. This permission is costly and beyond the financial scope and skill of scientific personnel. Thus, scientific advancement via trials necessitates commercial engagement, which relies on advantages for commercial partners regarding the business case and essential intellectual property protection to ensure competitive advantage. This may hinder development, especially if the advantages to patient care or cost savings are not readily evident, or if substantial expenditure is necessary before realizing a return on investment. A novel culture of research is necessary for decision-making tools, whereby stringent regulation is balanced with periodic case reviews. This would correspond with a learning organization rather than a randomized controlled trial and correlate more closely with standard clinical practice.

7. Conclusions

This narrative review has many strengths; it used a rigorous search approach to analyze two biomedical databases, evaluating almost 2500 papers, and it established defined goals that were addressed based on the collected information. Limitations include the repeatability of our results and their relevance outside high-income healthcare environments.This narrative review has identified deficiencies in our comprehension of ventilation practices and emphasized the need for a coordinated, tiered strategy based on implementation science to facilitate the use of open-loop Clinical Decision Support Systems (CDSS). Future study should delineate the determinants influencing clinical decision-making across all phases of mechanical breathing, both with and without Clinical Decision Support Systems (CDSS), chart clinical workflows, and develop implementation toolkits to facilitate use in clinical practice. A novel research approach, akin to a learning organization, that takes into account the commercial sides of device design, is necessary.

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استراتيجيات متعددة التخصصات لتحسين إدارة التهوية الميكانيكية الغازية في الرعاية الحرجة: الأدوار المحورية للتمريض والعلاج التنفسي

الملخص

الخلفية:تعد التهوية الميكانيكية الغازية (IMV) تدخلاً أساسياً للمرضى في الرعاية الحرجة، ومع ذلك، فإن تطبيقها غالبًا ما يختلف بسبب التفاعل المعقد بين حالة المريض، وميكانيكا الرئة، وقرارات الأطباء. تعد استراتيجيات التهوية المخصصة ضرورية للتقليل من مخاطر المراضة والوفيات المرتبطة بسوء إدارة التهوية.

الطرق:تقوم هذه المراجعة السردية بتلخيص الأدبيات الحالية حول النهج متعددة التخصصات في إدارة التهوية الميكانيكية الغازية، مع التركيز على أدوار التمريض والعلاج التنفسي. تم إجراء بحث شامل في قواعد بيانات MEDLINE و EMBASEللمقالات العلمية المنشورة باللغة الإنجليزية حتى عام 2023، مع استخراج منهجي للبيانات المتعلقة بعمليات اتخاذ القرار السريري، وتحديد الأدوار، ونشر أنظمة دعم القرار السريري (CDSS)

النتائج:كشفت النتائج عن تباين كبير في مسؤوليات اتخاذ القرار بين مقدمي الرعاية الصحية، حيث يتولى الممرضون غالبًا توجيه التقييمات المتعلقة بجاهزية الفطام، بينما يشرف الأطباء بشكل رئيسي على إعدادات التهوية الأولية وعمليات نزع الأنبوب. أظهرت دمج أنظمة CDSS في الممارسات السريرية وعوداً كبيرة في تحسين استراتيجيات التهوية، ومع ذلك، لا تزال هناك عوائق أمام التنفيذ، مثل مقاومة الأطباء والتأثيرات على سير العمل.

الاستنتاج:يعد تعزيز التعاون بين التخصصات والنشر الفعّال لأنظمة CDSS أمرًا بالغ الأهمية لتحسين نتائج المرضى في إدارة التهوية الميكانيكية. ينبغي أن تركز الأبحاث المستقبلية على توضيح محددات اتخاذ القرار وتحسين استراتيجيات التنفيذ لتسهيل تبني أفضل الممارسات في بيئات الرعاية الحرجة.

الكلمات المفتاحية:التهوية الميكانيكية الغازية، أنظمة دعم القرار السريري، التعاون متعدد التخصصات، التمريض، العلاج التنفسي.